UNIVERSITY OF PENNSYLVANIA

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GEORGE S. GESSNER

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IN PHYSICS

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PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
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THE LUMINESCENCE OF ZINC SULPHIDE UNDER THE ACTION OF ALPHA, BETA AND GAMMA-RAYS

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Abstract

The luminescence of zinc sulphide under the action of α, β and γ-rays was studied with an especially designed brass capsule. The zinc sulphide was exposed to the α-rays or β and γ-rays, or α, β and γ-rays from radium or its products, while the luminescent material and the exciting agent were kept separate. In this way the effect of these rays upon the luminescent material was observed, separately and collectively. The experiment was made under practically constant temperature. The luminosity time curves for the three types of capsules were consistent in characteristics. It was found that for a time there was a definite increase in brightness; then the luminescence decreased under the constant action of the rays and rose again to a second maximum. This was followed by gradual decrease with time as long as observations were taken. The decay of luminescence of zinc sulphide, after the removal of the radio active source, showed that the decay curve is not of the type whose ordinate can be expressed by a single exponential term.

Introduction

THE action of α, β and γ-rays from radium or its products, upon luminous compounds has been studied by several experimenters[1] during the last two decades and theories have been formulated to explain their results.

Przibram[2] and his students found that the luminescence of some minerals increased under the action of β-rays and then gradually decayed after passing through a maximum. Smith[3] found an increase in brightness at room temperature of chemically pure barium bromide.

Studies in luminosity of luminescent zinc sulphide under the action of α, β and γ-rays from radium or its products, up to this time, have been made using mixtures of the luminescent material and the radioactive exciting agent. One of the features of the present research was to keep the radioactive source separate from the luminescent material, thus avoiding the possible formation of complex products. Another feature was the use of a source of radiation which remained constant during the period of the experiment. Thus it was possible to observe the brightness as soon as the luminescent material was brought in contact with the radioactive source. This was not done in previous experiments on zinc sulphide because of the

[1] E. Rutherford, Proc. Roy. Soc. **83A**, 561 (1909–10), E. Marsden, Proc. Roy. Soc. **83A**, 548 (1909–10), Patterson, Walsh and Higgins, Proc. Phys. Soc. of London **4**, 215 (1917).

[2] K. Przibram and E. Kara-Michailova, Akad. Wiss. Wien, Ber **131**, 2A 285 (1923), **132**, 2A, 261 (1924).

[3] L. E. Smith, Phys. Rev. **28**, 431 (1926).

time taken for the source of rays to become constant. It was also thought desirable to use a strong source of radiation, hoping thereby to hasten the decay.

Not only were the radioactive source and the luminescent material kept separate but the luminescent material was kept inclosed in a capsule so that it could be studied before bringing it in contact with the radioactive source or after its removal.

Apparatus and Procedure

In order to keep the luminescent material separate from the radioactive source, brass capsules were prepared, as shown in Fig. 1, each consisting of five major parts. On a gold plate fitted snugly in a depression on the face of part (5) was placed a layer of radium sulphate in equilibrium

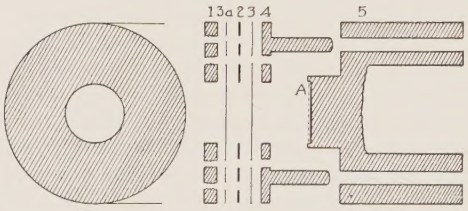

Fig. 1. Brass capsule.

with its decay products and covered with a coat of varnish. Such a plate furnishes a constant source of radiation permitting the α as well as the β and γ-rays to pass through. Part (4), serving to hold parts (1) and (5) together consists of a thin brass washer to which are fastened several legs fitting snugly into holes in part (5). Part (1) is a brass washer to which can be fastened part (2), an aluminum washer; a thin sheet of mica is

Table I

Capsule	Radium content	Rays emitted
1	0.293 mg	α β γ
2	0.522	α β γ
3	0.910	α β γ
4	0.815	α β γ
A	2.40	α β γ
B	.16	β γ
C	2.8	α β γ
D	Pol.	

placed between the brass washer and the aluminum washer and parts (1) and (2) are fastened together by means of small screws. The luminescent material was placed in the opening in the aluminum washer (2) and the sample as well as the aluminum washer were covered with a piece of very thin mica (3). Against this mica disk part (4) was fastened by means of small screws. Thus the sample was separated from the radioactive source and also protected from contamination by radium and its products.

Three different kinds of capsules were prepared: (A) where the mica disk (3) was thin enough to allow α as well as β and γ-rays to pass through (in some cases the mica was replaced by aluminum foil); (B) where the mica (3) was thick enough to allow only the β and γ-rays to pass through; (C) where the layer of radium sulphate was replaced by a polonium plate, giving off chiefly α-rays. Thus it was possible to study the effect of α-rays or β and γ-rays or α, β and γ-rays upon the sample of zinc sulphide.

The luminosities of the different samples were measured by means of a Nutting polarization photometer. The arrangement of apparatus is shown in Fig. 2. The apparatus is so arranged that by changing the distance between the standard lamp and the ground glass screen, its illumination of the screen can be controlled. The standard lamp S is supplied by means of storage batteries and its voltage maintained constant by a potentiometer arrangement, and a ballast lamp to stabilize the current for small variations in the battery voltage. Light from the standard lamp is reflected by the rhomb shown in Fig. 2, thus passing through the polarizing Nicol NP and the photometer cube C. Light from the sample B is reflected by the prism D thus passing into the photometer cube C, and is again reflected as shown in Fig. 2.

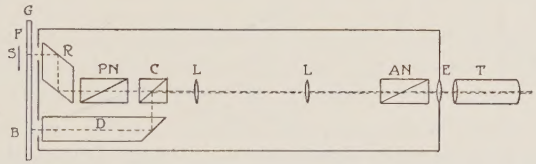

Fig. 2. Diagram of photometer.

In making an observation, the telescope is focused on the photometer cube and the field appears as two strips of reflected light from the sample B with the transmitted light from the standard lamp between them. By varying the intensity due to the standard lamp by means of the Nicol prism AN, the central strip is made alternately lighter and darker than the strips illuminated by the sample B until an intensity match is obtained. With the exception of the improvement in design of the capsule the apparatus is the same as that used by Smith[3] in his study of barium bromide. The reference lamp S was a 110 volt incandescent carbon filament lamp operated at 60 volts. This lamp was compared with a lamp standardized by the Bureau of Standards. A green filter F was interposed to produce a better color match.

The brightness of the samples was readily calculated from the scale readings of the photometer and the constants of the apparatus. The photometer was graduated in logarithms of the ratio of the illuminating power of the standard lamp to that of the sample. If K is the transmission coefficient of the filter, C_1 the candle power of the standard lamp, C_2 the candle power of the sample, d_1 and d_2 their respective distances from the ground glass screen G,

$$\log_{10}(KC_1/d_1^2) - \log_{10}(C_2/d_2^2) = x(\text{reading on photometer}).$$

If A is the area of the exposed luminous portion of the sample, the brightness B in apparent candle power per square cm is

$$B = (KC_1d_2^2)/(d_1^2 10^x A).$$

The sample of luminescent zinc sulphide approximately 0.020 cm in thickness was prepared and sufficient time allowed for the decay of the luminosity due to exposure to light in preparing. The sample was slipped on part (5) Fig. 1 and its luminosity read at intervals of a few minutes for the first hour, then at slightly longer intervals for the first day. All measurements were made at room temperature.

Results

This study has shown that for crystalline zinc sulphide, there is first an initial growth to maximum value, then a decrease in luminosity followed by a second growth to a maximum, and then a very slow decay.

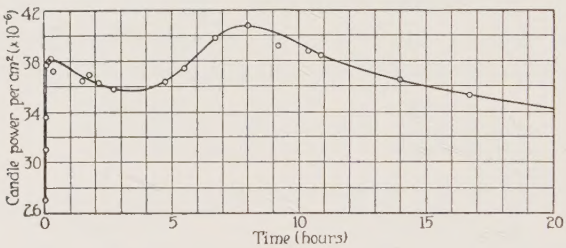

Fig. 3a. Luminosity curve, capsule (4), α, β, γ-rays. Zinc sulphide screen.

Figs. 3a and 3b show the variation of luminosity with time for two samples (4) and (A) (radium content given in Table I); from these curves will be seen that the maxima as well as the time required to reach these maxima are dependent upon the amount of radium present. Capsule (4) containing less radium than capsule (A) requires a longer time to reach the maximum values

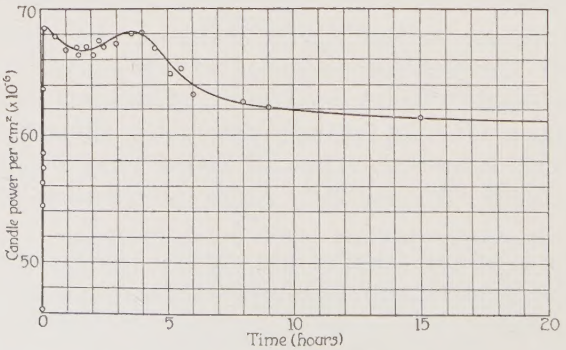

Fig. 3b. Luminosity curve, capsule (A), α, β, γ-rays. Zinc sulphide screen.

and these maxima are lower than for capsule (A). Similar results were found for capsules (1),(2), and (3). Capsule (1) for example, containing 0.293 milli-

grams of radium, required about 5 hours to reach the first maximum and about 15 hours to reach the second maximum. The maximum brightness for capsule (1) was 1.65×10^{-6} candle power per square cm. In all the above cases the sample of zinc sulphide was bombarded by α, β, and γ-rays.

Fig. 4 is a luminosity time curve for capsule (C). In this case the luminescent material was bombarded by β and γ-rays only. This curve also shows

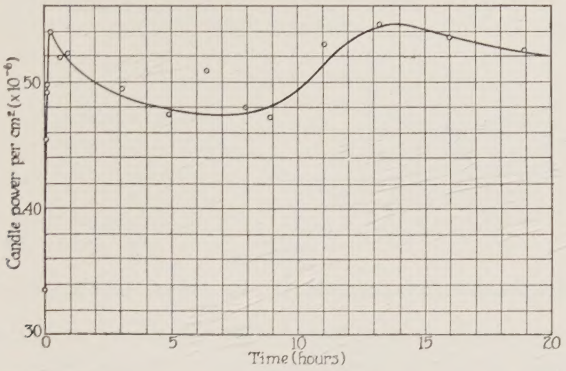

Fig. 4. Luminosity curve, capsule (C), β, γ-rays. Zinc sulphide screen.

the two maxima but the time required to reach the first maximum value was about 20 minutes and the second maximum about 13 hours.

Fig. 5 shows the curves of Figs. 3a, 3b and 4 plotted over a longer period of time. From this curve we can see that the rate of decay for capsule (A) after reaching its second maximum is greater than that of capsule (4). The

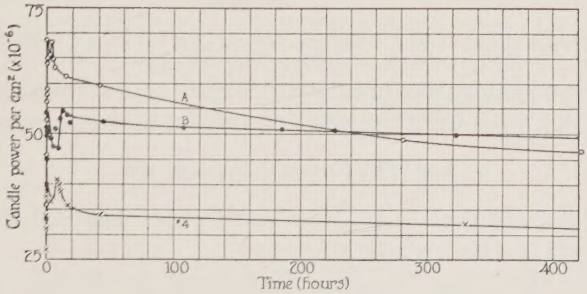

Fig. 5. Curves of Figs. 3a, 3b and 4 plotted over long periods of time.

decay of capsule (A) was not nearly so rapid as was expected from consideration of the amount of radium present in the two cases. It must also be noted that decay of luminescence for capsule (C) (which emits only β and γ-rays) after reaching the second maximum is much slower than for capsule (A).

The initial part of the luminosity time curve for capsule (D) is shown in Fig. 6. In this capsule the radium sulphate was replaced by a polonium plate so that the sample of zinc sulphide was bombarded chiefly by α-rays. Here also is seen the initial growth, decay and second maximum, followed by a gradual decay.

Fig. 7 shows the variation of luminosity with time for capsule (4) over a period of 400 days. Only one maximum is shown on this curve, this is due to the small time scale used in plottings. From this curve and similar curves

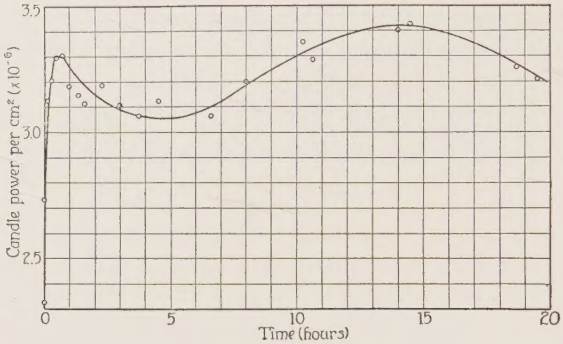

Fig. 6. Luminosity curve, capsule (D), Po α-rays. Zinc sulphide screen.

drawn over long periods, it was found that the decay of luminosity was not hastened as much as was expected by using a strong radium source.

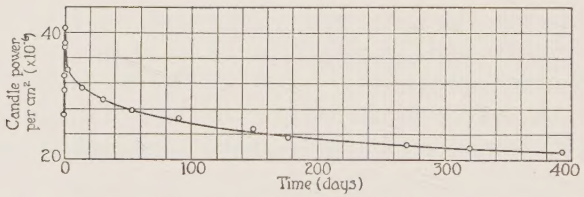

Fig. 7. Variations of luminosity with time for capsule (4) over a period of 400 days.

The theory of radioactive luminosity formulated by Walsh,[4] in which the variation in brightness with time was expressed by the equation

$$\log\left[(B/(b+B)\right]+a+kt=0$$

where a, b, and k are constants, does not fit the observed decay curves of brightness found in this investigation.

Neither do the other theories mentioned by Walsh on radioactive luminescence explain the initial growth or the appearance of the second maximum, which was characteristic of all the curves plotted, whether the material was bombarded by α or β and γ, or α, β and γ-rays.

Since the luminescent material and the radioactive source were kept separate, it was possible to study the decay of the luminescent material after the radioactive source was removed. The screens containing the luminescent material were placed in contact with the exciting agent until the maximum brightness was reached and then the radioactive source was removed and the rate of decay of luminosity with time was studied. Fig. 8

[4] J. W. T. Walsh, Proc. Phys. Soc. of London **39**, 318 (1926–27).

shows the relation of brightness to time. The broken curve (with ordinates on the right) shows the relation between logarithms of intensity and time. From this curve it can readily be seen that the luminosity time curve, for a sample after the exciting agent was removed, is not of the type whose ordinate can be expressed by a single exponential term.

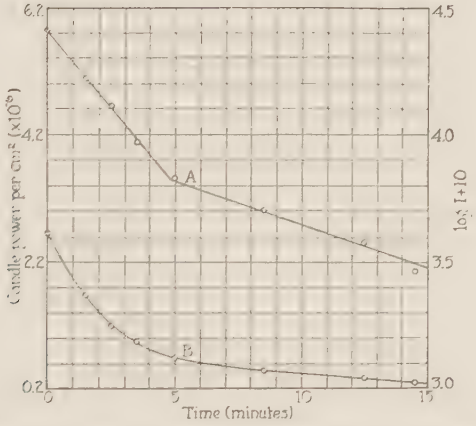

Fig. 8. Curve A = relation between logarithms of intensity and time.
Curve B = luminosity vs. time.

The fact that the decay of the zinc sulphide after removal of the exciting agent is not a single exponential may be an important factor in the formulation of a theory explaining the initial part of the brightness curves found in this investigation.

In conclusion the writer wishes to express his appreciation to Professor D. H. Kabakjian who suggested the problem, prepared the radium samples and under whose direction the work was carried out, and to Dr. E. E. Witmer for many helpful suggestions and discussions.